OFFICE OF RESOURCE CONSERVATION

State of Illinois

Grant Proposal

PROJECT TITLE: Development of Restoration Criteria for Freshwater Mussel Species in Greatest Need of Conservation

PROJECT NUMBER**:** T-99-R-1

DATES: October 1, 2015 – September 30, 2017

NEED:

The Streams Campaign of the IWAP has outlined a list of goals and actions to improve stream habitats and reduce stressors for focal species. Among these actions is to "Restore populations of imperiled and extirpated aquatic animals" (Criteria 4 of the Campaign). More specifically, action A indicates a need to "maintain populations at all currently-occupied locations and re-establish populations at 50% or more of historic locations where suitable habitat persists or can be restored"; action B suggests an action to "reintroduce native species into stream habitat where decimating factors have been eliminated and natural recovery is unlikely." The null alternative to these actions is the potential for continued decline of aquatic species in greatest need of conservation (SGNC) in currently occupied locations and an inability of these imperiled organisms to re-establish populations in areas of suitable habitat.

Baseline freshwater mussel data have been intensively collected across the state of Illinois since 2009 during T-53 and an assessment of freshwater mussel SGNC was completed in T-82. These efforts have established a knowledge-base of current and historical locations for freshwater mussels in Illinois. Additionally, through resources collected by Illinois employees (i.e., IDNR, IEPA, and INHS), we have access to a large dataset of biological and physical stream attributes, such as fish, habitat, and water quality data collected each year during IDNR/IEPA Intensive Basin Surveys.

We believe the logical next step towards re-establishment of populations is to investigate restoration options for mussel SGNC. We aim to combine previously collected data in a Bayesian Belief Network (BBN) to explore restoration options for mussel SGNC. Bayesian Belief Networks (BBN) are increasingly popular in natural resource management (Marcot et al. 2001; Andersen 2010; Kwak et al. 2011) because empirical data, professional opinion, and other parameters of interest (e.g., financial investment) can be incorporated in a relational framework to optimize an outcome. We plan to utilize BBN modeling software Netica (version 5.12 or later, Norsys Systems Corporation, Vancouver, BC, Canada), since this is the most widely used tool for

relational networks created in a Bayesian framework at this time. Mussel data for SGNC compiled in T-82 and suggested action items for the revised Wildlife Action Plan (as stated in Job 3 of T-82) established the need for potential restoration action in targeted regions in Illinois. We intend to build a BBN using existing data sets, professional opinion, and newly collected data to guide and inform future steps in the recovery process. Data compiling and streamlining for BBN use will likely be time-consuming; therefore, we proposed a minimum of 2 mussel SGNC as candidate species using our best judgment and literature review of similar project format (Lynch and Taylor 2010; Kwak et al. 2011; Hamilton et al. 2014; Lynch et al. 2015). If time allows, additional SGNC mussel species will be considered for BBN models.

The primary objective will be to establish the dominant factors limiting distribution of particular mussel SGNC and then investigate potential restoration options. Restoration options may include in-stream habitat restoration, re-establishment of host fish, and/or mussel augmentation. Following the results of the BBN, feasibility (e.g., financial and biological practicality) of the optimal restoration option will be investigated for management recommendations. Results can be utilized for future on-the-ground restoration or enhancement actions for selected mussel SGNC in targeted areas.

PURPOSE AND OBJECTIVES

The purpose of this project is to establish the dominant factors limiting distribution of particular mussel SGNC and then investigate potential restoration options.

Job 1: Determine target areas for necessary re-establishment of freshwater mussels in Illinois.

- 1.1 Review suggested actions completed in T-82 regarding mussel SGNC populations in Illinois and choose at least 2 mussel SGNC as candidate species for potential restoration.
- 1.2 For each species identified in Job 1.1, we will select at least 1 potential region within Illinois in need of mussel restoration.

Job 2: Compile component data for mussel, fish, and habitats to inform decision tool for the regions identified in Job 1.2.

- 2.1 Organize freshwater mussel data collected during T-53 and T-82 for use in a BBN.
- 2.2 Organize host fish data for selected mussel SGNC (from Job 1.1) for use in a BBN. Gather host fish distribution data for focal sites and species from IDNR biologists and INHS collection records.
- 2.3 Organize habitat associations for mussel SGNC and host fish for selected SGNC from Jobs 1.1 and 1.2 for use in a BBN.
- 2.4 Gather physical in-stream parameter data for the regions identified in Job 1.2., using a combination of Qualitative Habitat Evaluation Index (QHEI; Rankin 1989), Stream Habitat Assessment Protocol (SHAP; Illinois EPA 1994), and/or the multimetric habitat index for wadeable streams in Illinois (Sass et al. 2010).

Job 3: Develop a Bayesian Belief Network to provide region-specific information regarding restoration options.

Job 4: Ground-truth BBN results for feasibility.

4.1 Examine output for each chosen restoration option for sensitivity (to input) and feasibility.

4.2 Prepare report with formal recommendation for at least 2 species for chosen species/region combinations.

EXPECTED RESULTS AND BENEFITS:

This project will provide a detailed investigation into the restoration options for specific mussel SGNC. While an ideal situation for re-establishment of freshwater mussels would exist in the form of natural recolonization, research indicates that this process is unlikely to occur in certain situations (e.g., critically small populations; Strayer et al. 2004) or may take many years to occur in optimal situations (e.g., unimpounded waterways; Kappes and Haase, 2012). This project will inform managers of the most valuable restoration option for a specific scenario; examples of options include stock host fish, restore habitat, improve water quality, or augment mussels.

This project will be an initial step to provide guidance to state entities on direction of restoration efforts for mussels in wadeable streams. Reach-scale restoration efforts are occurring throughout Illinois to improve instream habitat, but augmentation of populations of SGNC may be necessary to re-establish viable communities. Investigating restoration criteria and feasibility is a necessary component to determine the future approach for conserving mussels in greatest need of conservation.

APPROACH:

Key personnel (A. Fritts, S. Douglass, A. Stodola, K. Cummings, T. Benson, and a researcher to fill a currently vacant position; INHS) plan to utilize a BBN as a decision tool to prioritize restoration options. BBNs are increasingly popular in natural resource management because empirical data, professional opinion, and other parameters of interest (e.g., financial investment) can be incorporated in a relational framework to optimize an outcome.

Job 1. Determine target areas for necessary re-establishment of freshwater mussels in Illinois.

1.1 Review suggested actions completed in T-82 regarding mussel SGNC populations in Illinois and choose at least 2 mussel SGNC as candidate species for potential restoration.

During T-82, a status revision of 29 of Illinois' mussel SGNC, as well as species with support to be listed as SGNC, was completed. Suggested actions for the Streams Campaign were completed, and several mussel SGNC were identified as candidates

for potential restoration (Section I; Douglass and Stodola, 2014). We will review this list in the context of potential restoration and identify at least 2 species that would be suitable for this project. Criteria that we would consider for selection of a species includes range contraction since 2000, extirpation from an entire drainage, critically low population numbers (e.g., functionally extinct populations), and inclusion on either the state or federal imperiled species lists.

1.2 For each species identified in Job 1.1, we will select at least 1 potential region within Illinois in need of mussel restoration.

Through the selection of focal species (Job 1.1), we will select a region in need of restoration for each species. Criteria used to select a focal region would include publicly-owned lands, areas undergoing current restoration (e.g., Kickapoo Creek in McLean County), areas within conservation opportunity areas (COA), and/or areas with existing partnerships or investments for restoration.

Job 2: Compile component data for mussel, fish, and habitats to inform decision tool for the regions identified in Job 1.2.

2.1 Organize freshwater mussel data collected during T-53 and T-82 for use in a BBN.

Mussel data were collected throughout the state during T-53 and historical presence and updated distributions for specific mussel SGNC were compiled during T-82. These data are well organized but will need to be streamlined/formatted for entry into an analysis network (Job 3). Data-formatting is a necessity with any modeling effort and can be tedious and time-consuming, thus we are including this as a specific Job to ensure the highest data quality.

2.2 Organize host fish data for selected mussel SGNC (from Job 1.1) for use in a BBN. Gather host fish distribution data for selected regions and species from IDNR biologists and INHS collection records.

Fish host relationships from primary and secondary literature sources were established for 68 species of freshwater mussels in Illinois during T-82. Fish host data will need to be compiled for the focal species and regions for this project, as selected in Job 1. Empirical data from existing data collection efforts (INHS and IDNR fisheries databases) will be the preferred source of host presence, although professional opinion may be used to fill data gaps. If host data are unavailable (via databases or professional opinion) for the selected species and regions of interest, we will shift efforts to different species and regions of interest (Job 1).

2.3 Organize habitat associations for mussel SGNC and host fish for selected SGNC from Jobs 1.1 and 1.2 for use in a BBN.

Perceived mussel habitat associations: physical habitat associations were compiled for each SGNC species in Illinois during T-82. We will determine the available habitat association data for each species selected for restoration (Job 1.1) for the mussel component. These data will be compiled from previous surveys, including habitat data collected during T-53, T-82, and/or other IDNR projects.

Fish habitat associations: host fish habitat associations must be considered for establishment or persistence of sustaining host populations. Habitat associations are available from previous projects (Metzke et al. 2012) but will need to be compiled.

Data-formatting is a necessity with any modeling effort and can be tedious and time-consuming, thus we are including this as a specific Job to allow time for quality assessment and control. Assessing data quality and format is particularly imperative when data are gathered from multiple sources.

2.4 Gather physical in-stream parameter data for the regions identified in Job 1.2., using a combination of Qualitative Habitat Evaluation Index (QHEI; Rankin 1989), Stream Habitat Assessment Protocol (SHAP; Illinois EPA 1994), and/or the multimetric habitat index for wadeable streams in Illinois (Sass et al. 2010).

In-stream habitat parameters and potential limiting factors will be compiled for focal regions selected in Job 1.2. These metrics may include instream physical habitat, chemical water quality parameters, barriers to colonization of host fish (e.g., dams), or other parameters. These data will be collected via field sampling at selected sites within the focal regions if recent, reliable data are not obtainable through other means. Obtaining the most current in-stream habitat data will increase the reliability of the final BBN analysis.

Job 3: Develop a Bayesian Belief Network to provide region-specific information regarding restoration options.

Data gathered in Jobs 1 and 2 will be used to inform a decision tool to prioritize restoration options for the focal species and regions. We plan to use a BBN to address our objectives: determine limiting factors to distribution of a particular mussel SGNC and the optimal restoration option for the focal region and species. An example of a simplified model framework is displayed in Figure 1.

We plan to utilize BBN modeling software Netica (version 5.12 or later, Norsys Systems Corporation, Vancouver, BC, Canada), since this is the most widely used tool for relational networks created in a Bayesian framework at this time. Previous researchers (Kwak et al. 2011) have also utilized other software packages for streamlining data-compilation (e.g., Elicitator software or Open Standards within software Miradi), thus other options may be pursued as needed.

Job 4: Ground-truth BBN results for feasibility.

4.1 Examine output for each chosen restoration option for sensitivity (to input) and feasibility.

The BBN will provide an optimal output based on the objectives for focal regions and species examined. Each outcome will need to be examined for sensitivity and feasibility, as well as how desirable the chosen option would be to stakeholders. A sensitivity analysis will be completed within Netica (or software selected) to determine the network component that has the greatest influence within the network. Feasibility of a restoration action will be examined for each of the selected species at the focal region(s). For example, if the BBN showed that augmenting a stream section with juvenile creek heelsplitters (*Lasmigona compressa*) was the optimal decision, we will determine feasibility of augmentation through a field site visit. This could include current state of biological literature, potential methodology, source populations, staff time, and financial investment.

An example of a cost analysis for stream restoration options is provided in Figure 2 (from Stewart-Koster et al. 2010) and our feedback loop is represented by the dotted lines in Figure 1.

4.2 Prepare report with formal recommendation for at least 2 species for chosen species/region combinations.

The formal report will be accompanied by a decision analysis tool that can be utilized by INHS and IDNR for future projects. This tool will allow agencies to use adaptive management strategies for the conservation of mussel SGNC. Depending on the software used, it may require acquisition of software (e.g., Netica) to operate the tool, although we intend for the results to be easily-accessible to IDNR staff. Netica also has a free version of their software available to all users. An example of a Netica input is included in Figure 3, which displays the type of tool we anticipate creating for use by IDNR staff. All inputs can be modified by the user to match a specific scenario of interest; however, some training and familiarity of the tool will be required (and can be offered by the PIs on this proposal). Further, we intend to investigate as many species or regions as project time allows (e.g., more

than the minimum of 2 species), however it is unknown how long it will take to compile the data for the models.

USEFUL LIFE:

Not applicable to this project.

PROGRAM INCOME:

Not applicable to this project. No income will be generated through these efforts.

MULTIPURPOSE PROJECTS:

Not applicable to this project.

GEORGRAPHIC LOCATION:

This 2-year project will be completed by staff of the Illinois Natural History Survey (Champaign, IL), INHS-Illinois River Biological Station (Havana, IL), and University of Illinois in Urbana-Champaign in cooperation with IDNR personnel located in Springfield. Habitat sampling for Job 2.4 will be conducted at the focal regions identified in Job 1.2. Site visits for assessment of feasibility (Job 4.1) will be conducted following the identification of recommended restoration actions.

PROJECT SCHEDULE/TIMELINE:

	10/15 - 12/15	1/16- 3/16	4/16- 6/16	7/16- 9/16	10/16- 12/16	1/17- 3/17	4/17- 6/17	7/17- 9/17
Job 1: Determine target areas for necessary re-establishment of freshwater mussels in Illinois.								
1.1 Review suggested actions completed in T-82 regarding mussel SGNC populations in Illinois and choose at least 2 mussel SGNC as candidate species for potential restoration.	x	x						
1.2 For each species identified in Job 1.1, we will select at least 1 potential region within Illinois in need of mussel restoration.	x	x	x	x				
Job 2: Compile component data for mussel, fish, and habitats to inform decision tool for the regions identified in Job 1.2.								
2.1 Organize freshwater mussel data collected during T-53 and T-82 for use in a BBN.	x	x	x	x	x	x	x	x
2.2 Organize host fish data for selected mussel SGNC (from Job 1.1) for use in a BBN. Gather host fish distribution data for selected regions and species from IDNR biologists and INHS collection records.		x	x	x	x	x	x	
2.3 Organize habitat associations for mussel SGNC and host fish for selected SGNC from Jobs 1.1 and 1.2 for use in a BBN.		x	x	x	x	x	x	
2.4 Gather physical in-stream parameter data for the regions identified in Job 1.2., using a combination of Qualitative Habitat Evaluation Index			x	x	x	x	x	x

(QHEI; Rankin 1989), Stream Habitat Assessment Protocol (SHAP; Illinois EPA 1994), and/or the multimetric habitat index for wadeable streams in Illinois (Sass et al. 2010).								
Job 3: Develop a Bayesian Belief Network to provide region-specific information regarding restoration options.		x	x	x	x	x	x	x
Job 4: Ground-truth BBN results for feasibility.								
4.1 Examine output for each chosen restoration option for sensitivity (to input) and feasibility.						x	x	x
4.2 Prepare report with formal recommendation for at least 2 species for chosen species/region combinations.						x	x	x

BUDGET:

PROJECT BUDGET			Project Totals					
	Off Campus	On Campus	INHS	INHS				
Expense Line Item	Request	Request	Match	Match	Total			
			Off Campus	On Campus		Federal	Non-Federal	Total
SALARIES & WAGES	87,500	98,000	0	51,664	237,164	185,500	51,664	237,164
FRINGE BENEFITS	34,248	36,477	0	20,221	90,946	70,724	20,221	90,946
TRAVEL	0	10,167	0	0	10,167	10,167	0	10,167
MATERIALS & SUPPLIES	0	5,180	0	0	5,180	5,180	0	5,180
CONTRACTUAL SERVICES	0	4,730	0	0	4,730	4,730	0	4,730
TELECOMMUNICATION SERVICES	0	0	0	0	0	0	0	0
EQUIPMENT (each item $5000+)	0	0	0	0	0	0	0	0
Total Direct Costs	121,748	154,554	0	71,885	348,187	276,302	71,885	348,187
Modified Total Direct Costs (MTDC)*	121,748	154,554	0	71,885	348,187	276,302	71,885	348,187
F&A-Sponsor (20% of Request)	24,350	30,911			55,260	55,261	0	55,261
F&A-UIUC (58.6% of Match) On Campus		0		42,125	42,125	0	42,125	42,125
Unrecovered F&A (20% vs. 24%) Off Campus			4,870		4,870			
Unrecovered F&A (20% vs. 58,6%) On Campus				59,658		0	64,528	64,528
Total Proposed Project Budget	146,098	185,465	4,870	173,668	510,101	331,563	178,538	510,101
Total Match Percentages	0.65			0.35		0.65	0.35	

PERSONNEL/PRINCIPLE INVESTIGATOR:

The personnel funds requested in this project will fund two full time research scientists for the project duration each year. One research scientist (Andrea Fritts) will be based at the INHS-Illinois River Biological Field Station in Havana, IL. The second research scientist position is a needed staff person that will be located in Champaign, IL. This position is currently vacant and needs to be filled by an ecologist (aquatic experience preferred) with experience in Bayesian statistical methods. Alison Stodola and Sarah Douglass (INHS, Champaign, IL) will be assisting on this project at 5% time for the duration of the project. Additional INHS and IDNR personnel listed below will be providing technical expertise to the project.

The following personnel from IDNR Office of Resource Conservation (ORC) will manage this project:

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RELATIONSHIP TO OTHER GRANTS:

T-53-P-001: During this project, over 900 consistently-collected mussel community samples were taken throughout the state at wadeable streams. The data collected in T-53 will be used to select focal species and regions using those baseline data.
T-82-R-1: During this project, status and distribution of mussel SGNC were completed. Habitat requirements, fish host requirements, current locations and historical localities were compiled for 77 species in Illinois. These data will be useful to help pinpoint regions in the state where populations may need to be restored, as well as the habitat and biological requirements for each species.

COMPLIANCE:

The IDNR will use its CERP (Comprehensive Environmental Review Process) as a tool to aid the Department in meeting NEPA compliance for the projects outlined under this grant proposal. It is the Department's policy to require CERP applications for all land disturbing activities unless those activities are covered by CERP exemptions (see the enclosed Comprehensive Environmental Review Process documents).

All work identified in this proposal is believed to be covered by categorical exclusions (see attached NEPA Checklist for details) with no known exceptions. If exceptions to the categorical exclusions are identified or if the scope of the work materially changes during the execution of the proposed project, the Federal Aid Division of the USFWS will be contacted to determine if additional NEPA compliance actions are needed.

All planned activities will also be in compliance with the Endangered Species Act. All determinations and documentation will in accordance with the current established U. S. Fish and Wildlife Service protocols for Section 7.

All planned activities will be in compliance with the National Historic Preservation Act and the Council on Historic Preservation Act. All determinations and documentation will be in accordance with the terms of the Programmatic Agreement, as amended, effective September 23, 2002.

When applicable, those planned activities which involve a floodplain and/or jurisdiction wetlands will be done in accordance with Presidential Executive Orders 11988 and 11990.

When applicable, those planned activities which involve programs and/or site improvements will be done in accordance with Section 504 of the Rehabilitation Act and the Americans with Disabilities Act.

A series of reports will be written that analyzes the mussel data collected together with other information gathered as part of T-53-P-001 and T-82-R-1. These reports will be available to the public. Data collected through this project will be made available to the public through the INHS collections database and/or the IDNR SSD. IDNR staff will be available to the public to provide additional explanation to enhance the understanding of mussel data and its use for evaluating Illinois streams.

BUDGET JUSTIFICATION:

Personnel Services: We request funds to support two full time research scientists for the project duration, one located at INHS in Champaign (currently a vacant position that needs to be filled) and one located at the INHS-Illinois River Biological Station in Havana, IL (Andrea Fritts). We also request funds to support both Alison Stodola and Sarah Douglass (INHS-Champaign, IL) at 5% time for their involvement in this project. We also request funds for a non-student hourly to assist with field and professional input surveys and other computing tasks. All personnel will be involved in the collection, analysis, research, and reporting of project data. The salaries of Kevin Cummings and Thomas Benson, used for INHS cost sharing, are paid from the Illinois Natural History Survey operating funds and are at no cost to the sponsor. Cummings will provide a >30 years of mussel biology experience which will be highly useful for the aspects of the BBN that require professional opinion. Cummings, curator of malacology, will also provide access and database support to the ~80,000 cataloged records of freshwater mollusk data. Benson will provide support for biostatistics, quantitative biology, and Bayesian network building.

Fringe Benefits: These funds are needed in accordance with the monies budgeted for personnel services above.

Travel: This project will require some field travel to visit potential restoration regions to gather habitat data and conduct the feasibility portion, as well to meet with other professionals to compile professional opinion. Travel is estimated at 500 miles per week at $.50 per mile for 6 weeks ($1500); hotel costs were estimated for two rooms per night at $90 per night, three nights each week for the 6 week field season ($3240). Food costs were estimated at $98 per person each week for the 6 week field season ($1176). Travel during the field component totals $5916. This project will use the effective University of Illinois mileage reimbursement rate found at http://www.fs.uiuc.edu/campusservices/gcp/carpool/carpool.cfm at the time of mileage accrual in order to recoup costs from future gasoline price increases.

Research scientists will also present the research findings at professional scientific meetings, including the Freshwater Mollusk Conservation Society (FMCS) International Symposium, out-of-state in Cleveland, OH in April 2017; the Illinois Chapter of the American Fisheries Society (AFS), in-state in March 2016 & 2017; and the Society for Freshwater Science Annual meeting (SFS), out-of-state Raleigh, NC in May 2017. The following travel expenses will be incurred for professional meetings:

Conference travel: In-state								
Meeting	**Location**	**Date**	**# of attendees**	**per diem**	**lodging**	**mileage**	**airfare**	**Estimate**
IL Chapter American Fisheries Society	Springfield, IL	Mar-16	2	$192	$280	$150	na	$622
IL Chapter American Fisheries Society	TBD	Mar-17	2	$192	$280	$157	na	$629
						In state total		**$1,251**

Travel: Out-of-state								
Meeting	**Location**	**Date**	**# of attendees**	**per diem**	**lodging**	**mileage**	**airfare**	**Estimate**
Freshwater Mollusk Conservation Soc.	Cleveland, OH	March-17	2	$320	$542	$550	na	$1,412
Society of Freshwater Science	Raleigh, NC	May-17	1	$160	$400	na	$300	$860
Netica training	Vienna, VA	Jan-16	1	$128	$300	na	$300	$728
						Out of state total		**$3,000**

Travel may also be needed to fund one research scientist to attend a specialized training session to use Netica or a similar BBN tool. Bayesian statistics require some knowledge or background to properly implement a complicated tool such as the one we propose. While the research team possesses the biological knowledge to fulfill some of the components, further expertise may be needed to build the network. We request travel funds for one scientist to attend a training seminar or workshop that specializes in Netica and BBN in the event that such training is deemed necessary during project development. Examples of this training are offered by Innovative Decisions, Inc (offers recurrent training sessions in Vienna, Virginia). Estimated travel costs for this training (or a similar training solution) include 1 domestic flight ($300), per diem for 4 days at $32 per day ($128), and hotel costs for 3 nights at $100 per night ($300). Total travel cost for training is estimated at $728.

Materials & Supplies: Supply funds are needed to provide support for field supplies and computing resources. Funding is requested for one computer for one of the research scientists. This is a computer-intensive research program, which will necessitate the purchase of a desktop computer to be used specifically for this project by one of the full time researchers. Funds are also requested to pay for publishing costs of scientific documents and manuscripts.

Contractual: Bayesian statistics require some knowledge or background to properly implement a complicated tool such as the one we propose. Contractual funds will be needed to cover the tuition costs of a Bayesian training course with an estimated cost of $2000. Additionally, contractual funds will be used to cover conference registration fees and other contract-related expenses (e.g. printing posters). Attendance at conferences will directly benefit the project by the research scientists receiving feedback from other professionals on ways to improve sampling methods and data analysis. Conference registration is requested for AFS 2016 and 2017, FMCS 2017, and SFS 2017, and efforts will be made to pursue travel awards to help offset these costs.

Meeting	**Date**	**Registration**	**# of attendees**	**Total reg.**
IL Chapter American Fisheries Society	Mar-16	$170	2	$340
IL Chapter American Fisheries Society	Mar-17	$170	2	$340
Freshwater Mollusk Conservation Socie	March-17	$450	2	$900
Society of Freshwater Science	May-17	$450	1	$450
Netica training	Jan-16	$2,000	1	$2,000

Equipment: No request within this category

Indirect costs: Calculated on all requested dollars at 20% of modified total direct costs. Indirect costs on cost share funds are calculated at 58.6% (on campus rate) or 24% (off campus rate).

Cost-sharing: Provided by the salary, benefits and associated indirect costs of Kevin Cummings and Thomas Benson. Mr. Cummings will be providing 16% time ($10,500 salary per year, $21,000 total) and Dr. Benson will be providing 20% time ($15,332 salary per year, $30,664 total). Additionally, we will use unrecovered F&A (difference between the negotiated 20% vs. the on campus 58.6% rate & the off-campus 24% rate) to meet the required 35% non-federal cost share commitment.

GENERAL:

Literature cited

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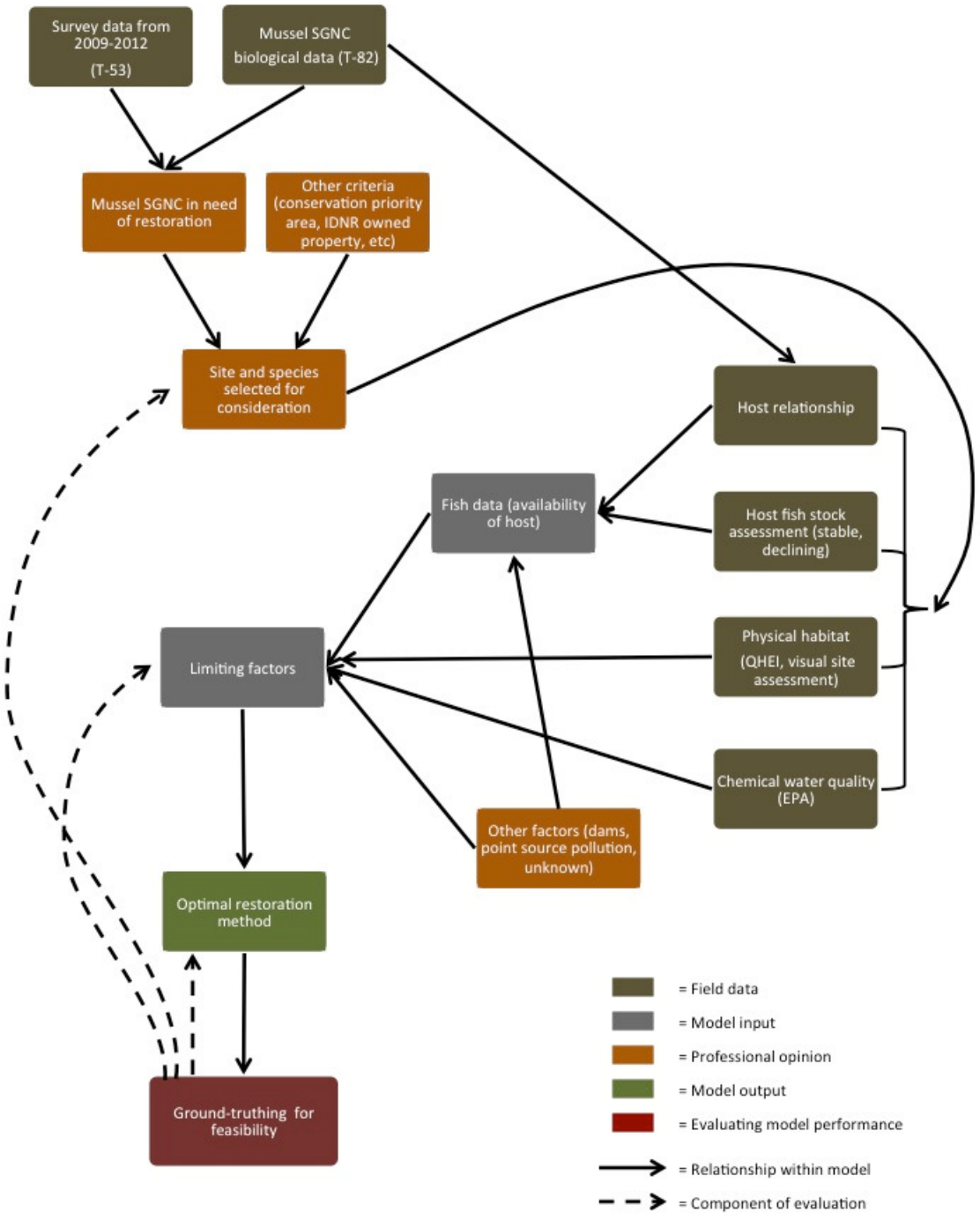

Figure 1. Example of simplified model structure for determining restoration options.

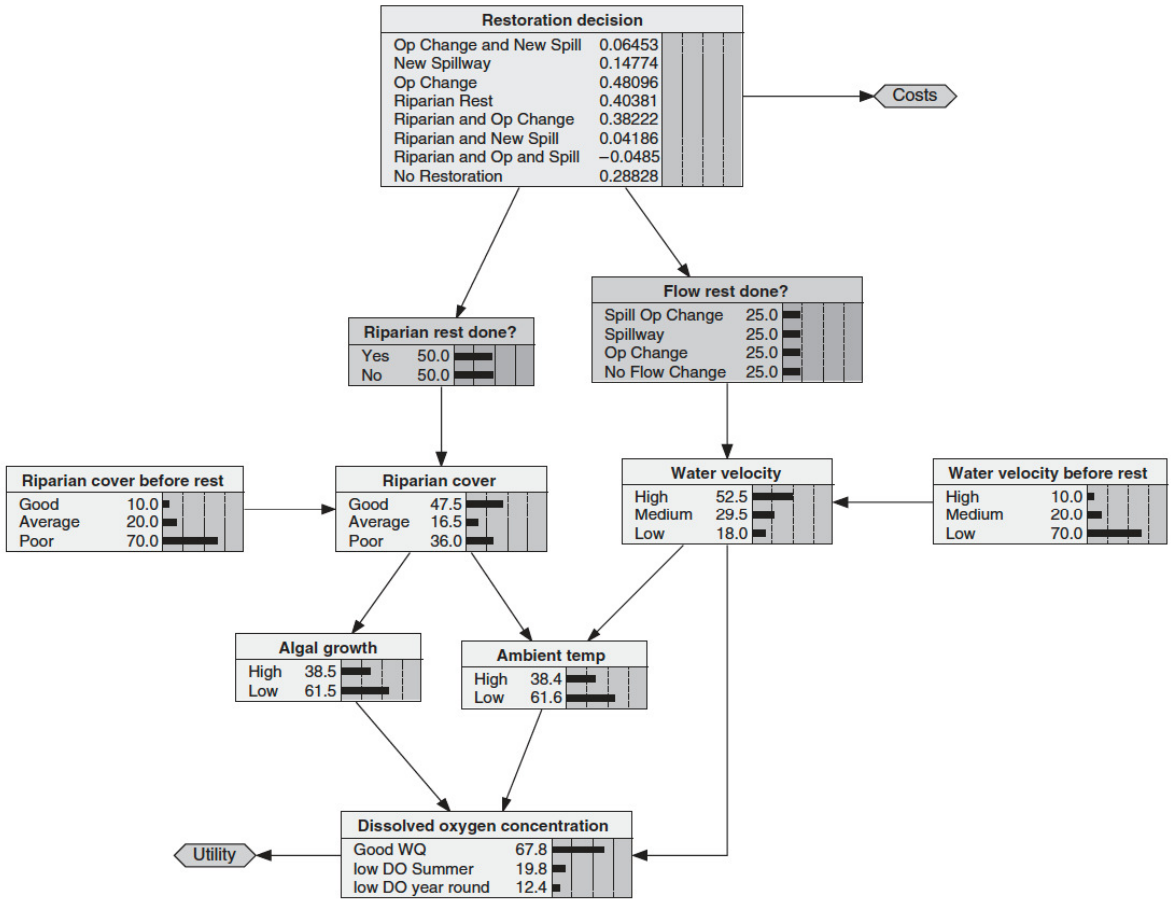

Fig. 4 Bayesian decision network incorporating costs of flow release versus riparian revegetation and the utility of each state of DO concentration. The decision node, restoration decision, illustrates the decision that maximises the utility based on costs and utilities from Table 2 averaged across all conditions in the network, operational changes to the reservoir (utility = 0.481).

Figure 2. Example BBN from Stewart-Koster et al. (2010) investigating varying restoration options.

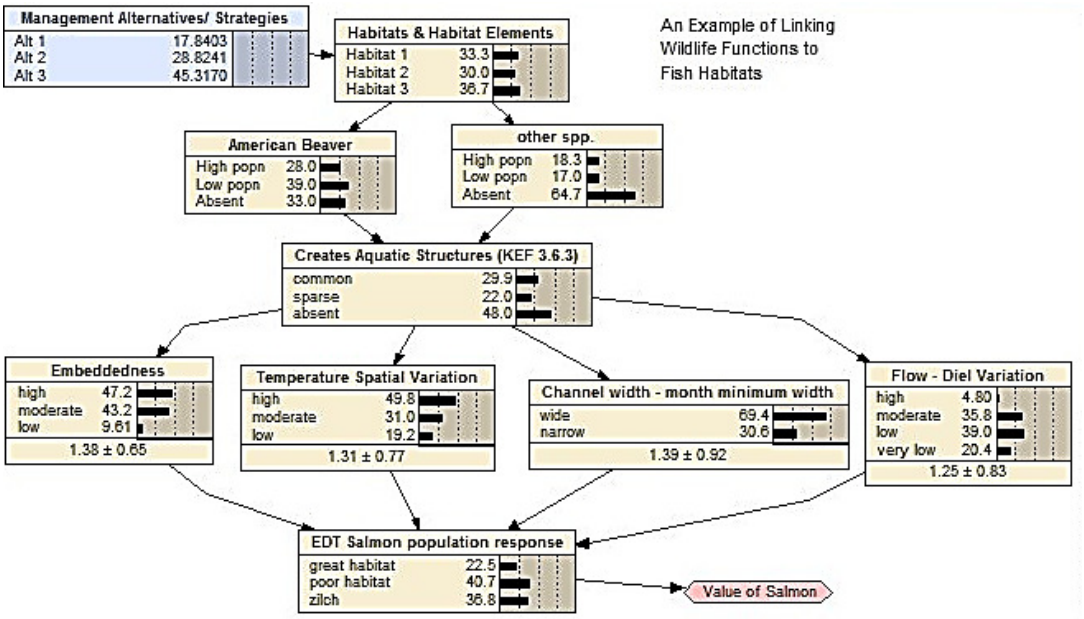

Figure 3: Example of a Netica input, which would be the type of tool available to IDNR staff for future restoration decisions. (Model by Bruce G. Marcot.)